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(54) System for converting particulate matter in gasoline engine exhaust gas

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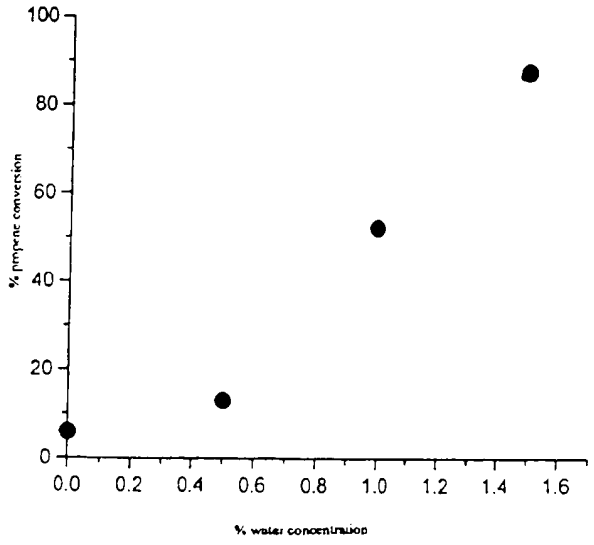

Fig. 4

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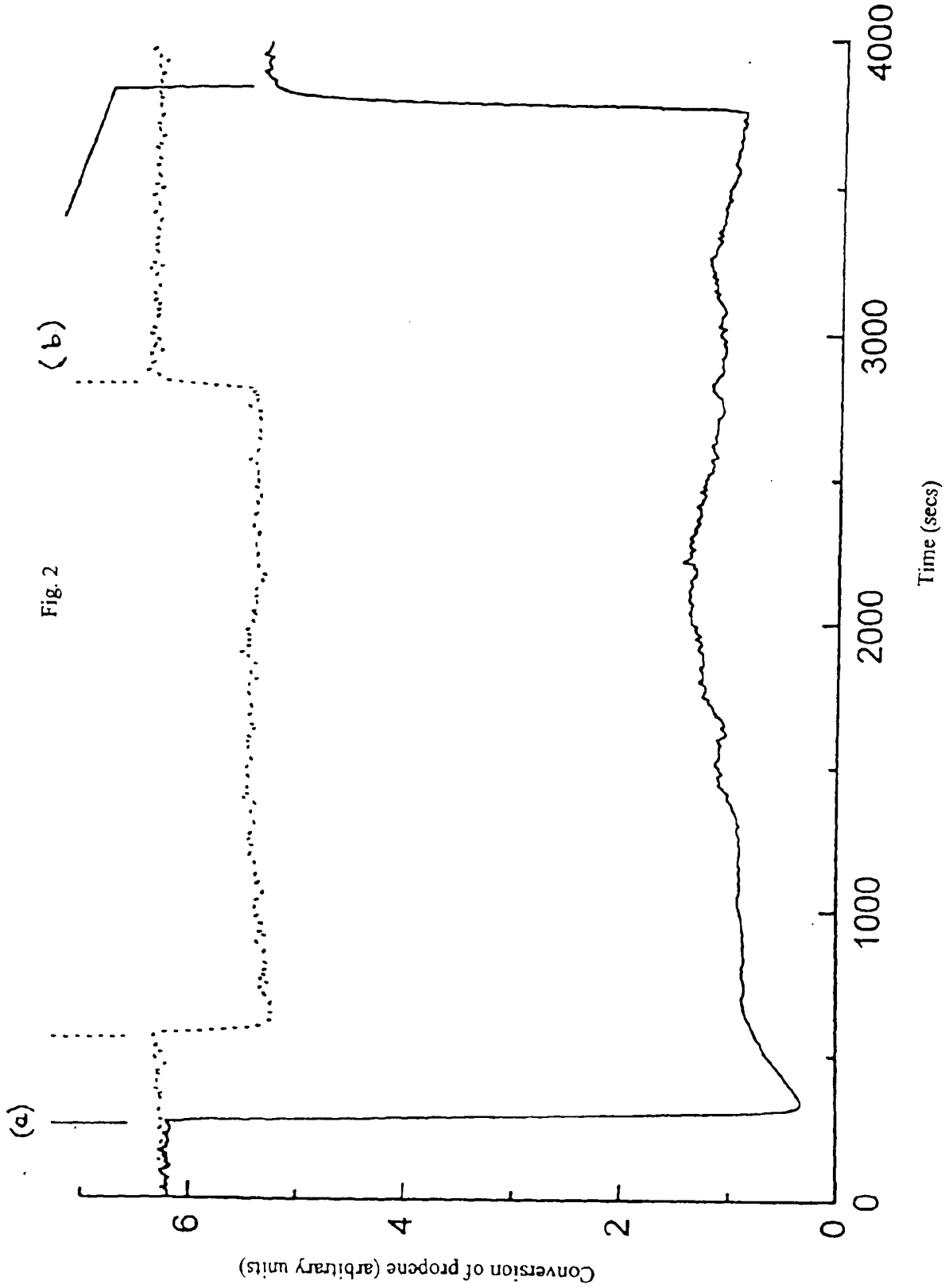
(a)
(b)
Conversion of propene (arbitrary units)
0
2
4
6
0
1000
2000
3000
4000
Time (secs)

Fig. 2

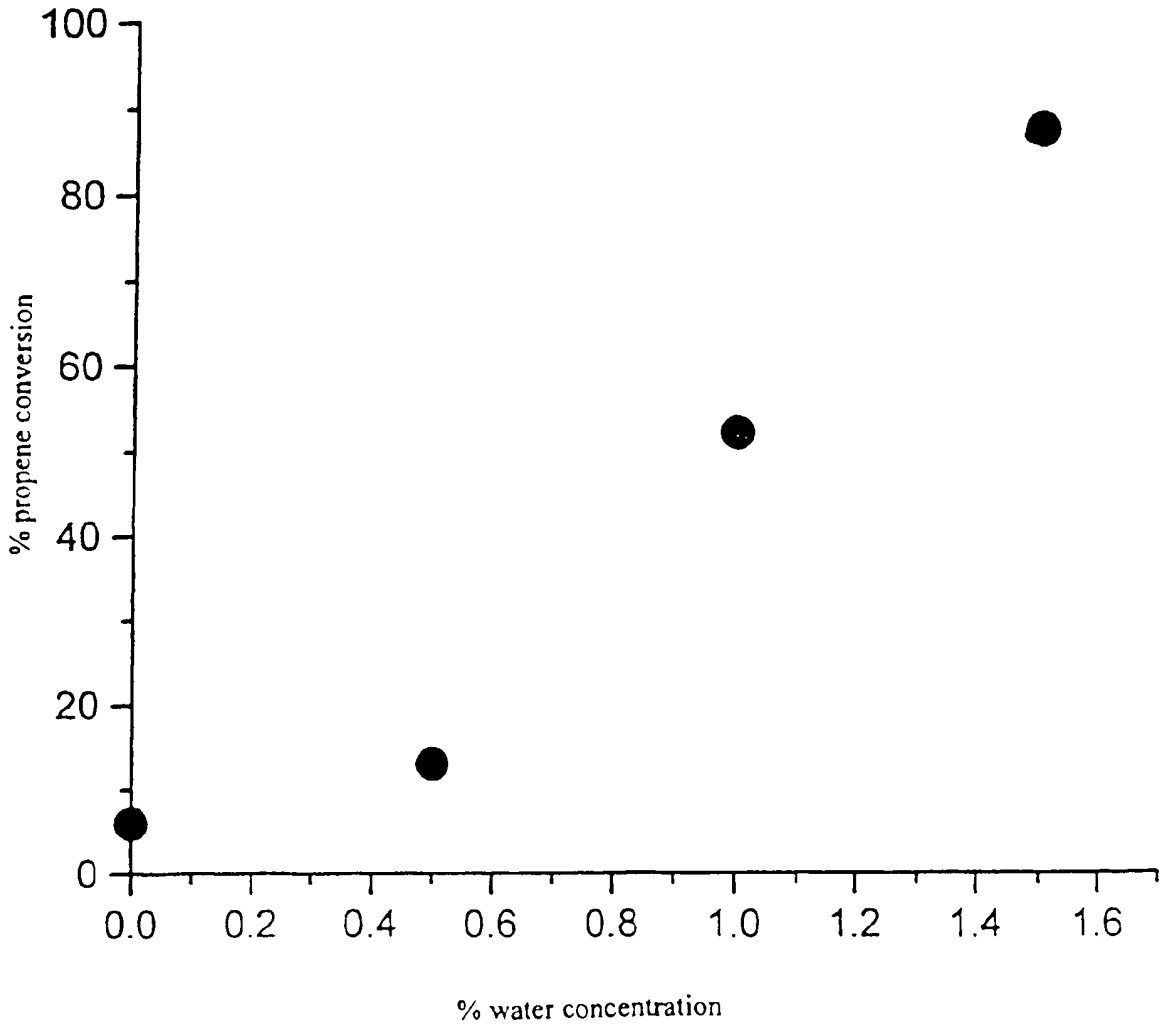
100
80
60
40
20
0
% propene conversion
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
% water concentration

Fig. 4

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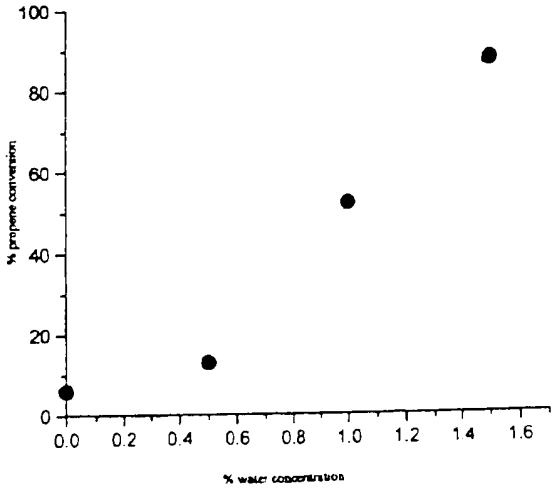

Fig. 4

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 00 30 6902

This annex lists the patent family membersrelating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDF file on
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08-05-2001

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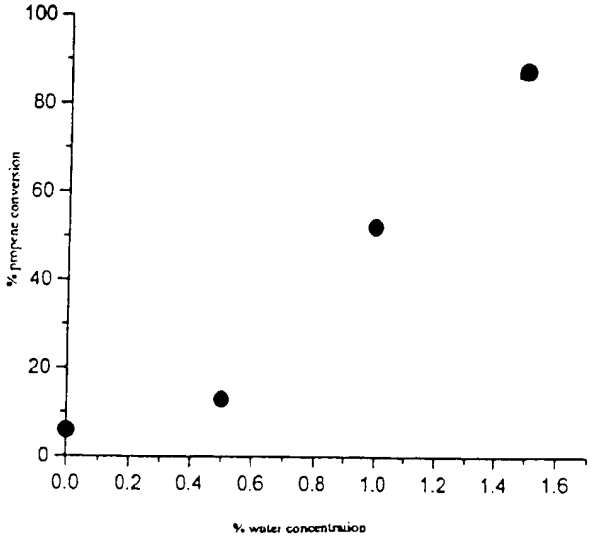

Fig. 4

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[0012] We are not aware of any efforts having been made specifically to remove PM from exhaust gases of stoichiometrically-operated engines.

[0013] We have now discovered that, by treating water vapour present in exhaust gases from a stoichiometrically-operated gasoline engine with a plasma, the plasma-treated water vapour can be used to convert PM, which can be disposed on a filter, and/or to oxidise NOx to NO_2, and to use this NO_2 to combust the PM. According to one aspect, the present invention provides the use of plasma-treated water vapour as an oxidant to convert particulate matter (PM) trapped on a filter disposed in an exhaust system, and/or to oxidise NO and/or N_2 to NO_2, which water vapour, PM, NO and N_2 is present in an exhaust gas of a stoichiometrically-operated gasoline engine, wherein the NO_2 is then used to combust the PM.

[0014] The present invention has the advantage that the benefits of the CRT™ are brought to exhaust systems of stoichiometrically-operated gasoline engines. Furthermore, it has been reported that the oxidation of NO to NO_2 by plasma occurs without oxidising SO_2 to SO_3 which can limit the application of CRT™ in diesel systems to low sulphur content fuels i.e. <50 ppm. We believe that the present invention enables use of the CRT™ concept with fuels of higher sulphur content more typical of gasoline currently available i.e. ~350 ppm.

[0015] For the avoidance of doubt, by "stoichiometrically-operated gasoline engine" we mean an engine which is designed to be operated wholly stoichiometrically, and not e.g. run lean during part of the engine cycle, and stoichiometrically during the remaining part. Non-stoichiometrically operated engines include gasoline-direct injection engines, engines in which the exhaust system includes a NOx trap or partial lean-burn gasoline engines in which stoichiometric operation occurs e.g. during acceleration or motorway driving.

[0016] For the purposes of the present invention, a plasma is a gas in which there are free electrons, radicals and ionised molecules, atoms and molecules in various states of excitation. It is a gas consisting of positive and negative charges which has a tendency to remain overall electrically neutral. In a non-thermal plasma the mean energy of an electron is considerably higher than those of the other components of the gas.

[0017] It is believed, although we do not wish to be bound by any theory, that in the present invention NO_2 may be generated not only by oxidation of NO in the exhaust gases, but also by oxidation of nitrogen to yield NO, which is itself then converted to NO_2. It should also be understood that the oxidant catalytically generated from NO or N_2 is not necessarily all NO_2. It may be, in whole or part, N_2O_5, N_2O or equivalent oxidant derived from NO in the exhaust. For ease of reference, however, the oxidant is simply referred to herein as NO_2.

[0018] Generally, the concentration of water vapour will be around 5%. A further preferred use of the invention is that some of the water vapour in the exhaust gas is derived from a source other than the combustion of the gasoline. This has the advantage that the amount of plasma-treated water vapour oxidant present in the exhaust gas can be adjusted to suit the particular load on the engine and hence the levels of NOx and/or PM present in the exhaust gas. The source can be a supply means controlled by the vehicle's engine control unit (ECU). One way of adjusting the level of additional water vapour input into the exhaust gas is by negative- and positive-feedback from sensors present in the exhaust system as part of the vehicle's on-board diagnostics (OBD). Alternatively, the level of water vapour-addition can be pre-programmed to a particular set of conditions e.g engine revs and/or acceleration and stored in the ECU as maps.

[0019] Preferably, the invention further comprises the use of the oxidation of the NO and/or N_2 to NO_2 to promote NOx or hydrocarbon light-off over a catalyst consisting of an oxidation catalyst.

[0020] Light-off over a catalyst is the temperature at which the catalyst is 50% efficient in catalysing a reaction NO_2 is generally more reactive than NO, so the conversion of NO to NO_2 can promote NOx light-off. However, under stoichiometric conditions the conversion of NO to NO_2 is very difficult using conventional catalytic techniques, because O_2 reacts preferentially with CO, hydrogen and gaseous hydrocarbons. Accordingly, the use of the present invention to make NO_2 can also be used to promote light-off over a suitable oxidation catalyst for both NOx and hydrocarbons.

[0021] In a further aspect, the invention provides a system for converting PM in an exhaust gas, which system comprises a stoichiometrically-operated engine and an exhaust system including a plasma generator for converting water vapour in the exhaust gas into an oxidant and a filter downstream of the plasma generator. Preferably the plasma generator and the filter are close coupled, i.e. positioned immediately adjacent to one another. In a further preferred feature, the system can include means for supplying water vapour upstream of the plasma generator.

[0022] Desirably, the system further comprises a catalyst consisting of an oxidation catalyst, which can be Pt or Pd or mixtures of the two, but is preferably Pt.

[0023] The plasma generator can be of any suitable type. For example, it may be of the corona discharge, surface plasma discharge, dielectric barrier discharge type or be a dielectric packed bed or electron beam reactor. The plasma generator can be enhanced by electromagnetic radiation, such as microwave radiation. Optionally, it may be positioned to treat all or a portion of the exhaust gases.

[0024] The filter used may be, for example, a woven or knitted wire filter, or a wall flow filter of generally known type. For certain vehicles, especially light cars or vans it may be necessary or desirable to use a filter design which collects only 80% or so by weight of the total

sisting of an oxidation catalyst for NOx and hydrocarbons.

4. A system for converting PM in an exhaust gas, which system comprises a stoichiometrically-operated engine and an exhaust system including a plasma generator for converting water vapour in the exhaust gas into an oxidant and a filter downstream of the plasma generator.

5. A system according to claim 4, wherein the plasma generator is of the corona discharge, surface plasma discharge, dielectric barrier discharge type or is a dielectric packed bed or electron beam reactor.

6. A system according to claim 4 or 5, wherein the plasma generator and the filter are close-coupled to one another.

7. A system according to claim 4, 5 or 6, further comprising a catalyst consisting of an oxidation catalyst.

8. A system according to claim 7, wherein the oxidation catalyst is Pt or Pd or mixtures of the two, preferably Pt.

9. A system according to claim 4, 5, 6, 7 or 8, further including means for supplying water vapour to upstream of the plasma generator.

10. A system according to any of claims 4 to 9, wherein the filter is catalysed.

11. A system according to claim 10, wherein the filter catalyst comprises a base metal and is preferably a combination of lanthanum, caesium and vanadium pentoxide or is Pt on MgO.

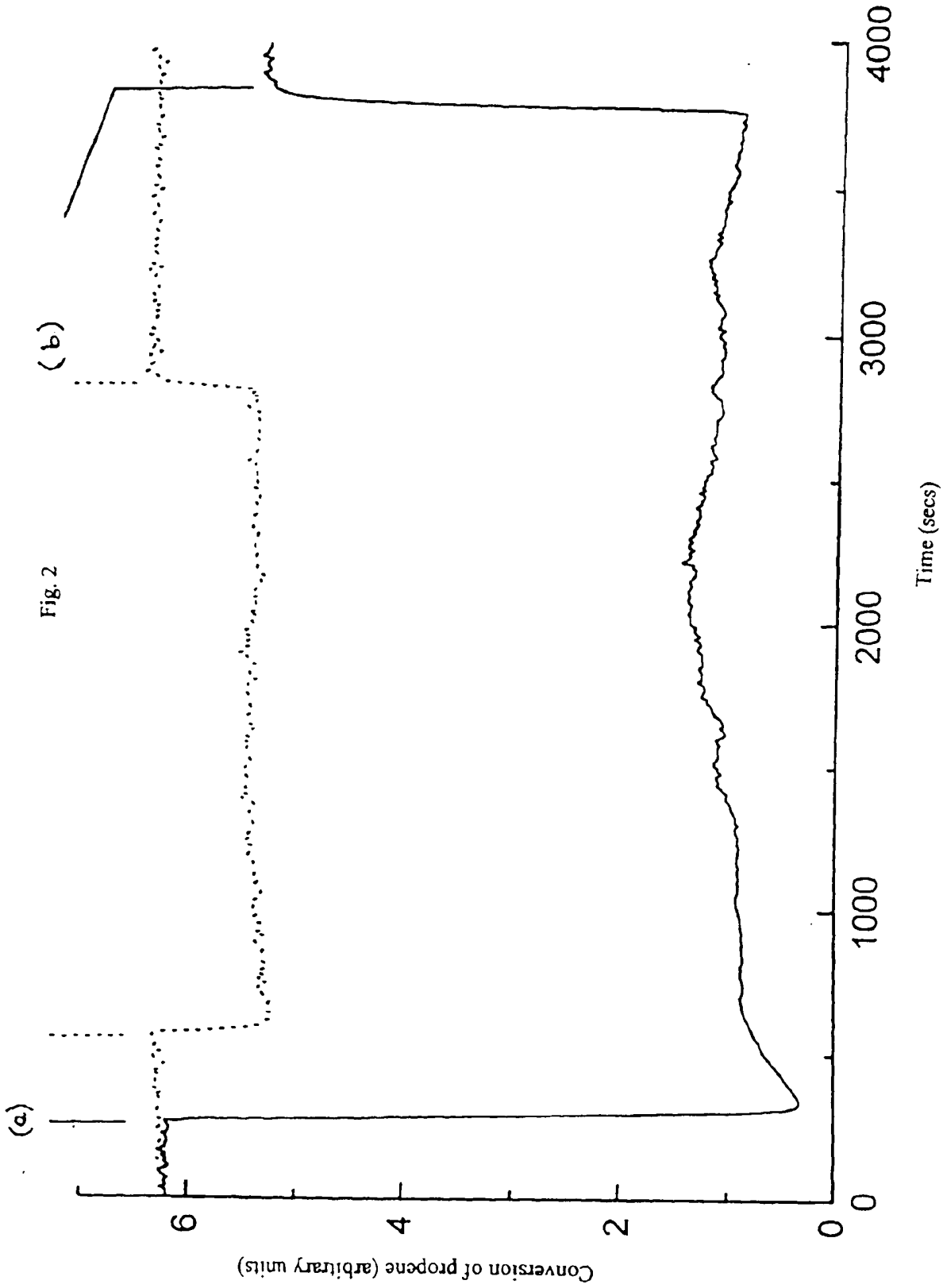
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Fig. 2

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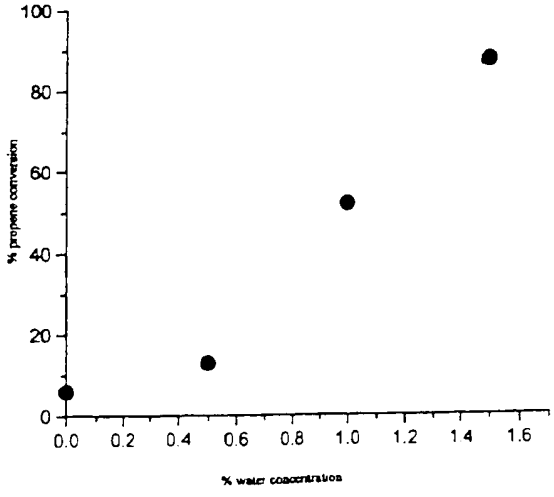

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